1

COMPONENT PART NOTICE

THIS PAPER IS A COMPONENT PART OF THE FOLLOWING COMPILATION REPORT:

TITLE: Workshop on Design Loads for Advanced Fighters: Meeting of the Structures and Materials Panel of AGARD (64th) Held in Madrid (Spain) on 27 April-1 May 1987.

TO ORDER THE COMPLETE COMPILATION REPORT, USE AD-A194 869.

THE COMPONENT PART IS PROVIDED HERE TO ALLOW USERS ACCESS TO INDIVIDUALLY AUTHORED SECTIONS OF PROCEEDING, ANNALS, SYMPOSIA, ETC. HOWEVER, THE COMPONENT SHOULD BE CONSIDERED WITHIN THE CONTEXT OF THE OVERALL COMPILATION REPORT AND NOT AS A STAND-ALONE TECHNICAL REPORT.

THE FOLLOWING COMPONENT PART NUMBERS COMPRISE THE COMPILATION REPORT:

AD#: AD-P005 762 thru AD#: AD-P005 770
AD#: AD#:
AD#: AD#:

DTIC FORM 463 MAR 85

OPI: DTIC-TID

1V
3-1-3-12
008700

AD-P005 764

CHANGES IN USAF STRUCTURAL LOADS REQUIREMENTS

Daniel Sheets and Robert Garami
Loads and Dynamics Branch
Aeronautical Systems Division
ASD/ENFSL, Wright-Patterson Air Force Base OH 45433-6503
USA

ABSTRACT

The new General Specification for Aircraft Structures, MIL-A-87221 (USAF), does not establish the traditional, fixed requirements, but instead it presents the current tailored approach to establishing structural loads requirements. In most cases the previous specifications set arbitrary load levels and conditions to be used in aircraft design. These requirements were based on historical experience, without consideration of future potential needs or capabilities brought about by technology advances. Instead, the new philosophy requires that loading conditions be established rationally for each weapon system based on anticipated usage. Also, compliance with each condition must be verified by analysis, model test, or full scale measurement.

INTRODUCTION

During the late 1970s, several conditions came together that caused the US Air Force to develop new aircraft structural specifications. While the USAF has always had a policy of reviewing, revising, and upgrading existing specifications, there were factors favoring a new approach. The contracting and legal authorities believed that the existing system of many layers of specifications needed to be simplified. Also, rapidly advancing structural technologies, coupled with new realms of performance and control capabilities, demanded that the structural specifications address much wider range of conditions while using an ever widening mix of technologies. The new military specification for aircraft structures, MIL-A-87221 (USAF), is a major deviation from past requirement practices. It establishes weapon system uniquely tailored structural performance and verification requirements for airframes based on an in-depth consideration of operational needs and anticipated usage. In the past, specifications set arbitrary conditions, levels, and values to be used in the design of broad categories of aircraft.

Various sources have alleged that design requirements have not kept pace with current usage practices; especially in the area of flight combat maneuvers. These allegations ignore the new requirement philosophy and are wrong for several reasons. The specification, MIL-A-87221 (USAF), does not preclude the consideration of any type of loading situation. The new specification actually requires the consideration of any loading condition that can be identified for either analysis, model testing, or full scale measurement. Therefore, if a loading condition is overlooked, the fault is not with MIL-A-87221 since it is not a set of rigid, pre-determined requirements.

Thus, this new approach does place a greater reliance on the designer's insight and ability to correctly anticipate the actual service loads. The term designer represents a broad spectrum of individuals associated with the USAF, System Contractor, and not just from the System Project Office which manages system development for the USAF. Anyone attempting to use the specification must understand that this one document covers all types of aircraft; from light observation, to the largest transport, to the fastest fighters, to any of the most advanced flight vehicles. Therefore, any application of this new specification must be tailored to the specific type of aircraft under design. It should also be understood that no two aircraft designs, even of the same general type, will have the same, identical, anticipated usage. Therefore, not only must the detail design specification be tailored to a specific type or category of aircraft, but it must also reflect the specific anticipated usage of the aircraft being designed and performance capabilities brought about by technology improvements in aerodynamics, control system integration, materials, and human factors.

STRUCTURAL LOADING CONDITIONS

The general organization of MIL-A-87221 is shown in figure 1. Structural loading requirements are developed through the application of section 3.4 of the appendix. The verification of these requirements is established by the use of section 4.4, also of the appendix. This procedure when incorporated into the new specification gives the user the best features of both a checklist approach and total design freedom. The loading requirement section 3.4, is divided into flight and ground conditions as shown in figure 2. The flight and ground conditions are divided into subsections as shown in figures 2a and 2b respectively. Each of the many subsections contain various specific load sources which the designer can either accept or modify as appropriate. During aircraft design, particular care must be exercised in defining both the structural loading conditions and the associate distributions used to design the airframe, which in turn directly influences the performance and reliability of the aircraft. No single section of the specification can be addressed independently. All requirements pertaining to all technologies must be considered as one unified entity. Both flight and ground operating conditions must be based on the anticipated usage, unique to a specific aircraft design

effort. These conditions reflect the operational usage from which design loads shall evolve.

Even though this new approach gives the designer considerable flexibility, the designer is not abandoned to establishing all requirements without guidance or assistance. In both the requirement and verification sections, numerous possibilities are presented for consideration. The applicability or non-applicability of each suggested requirement or verification can be indicated by inserting either "APP" or "N/A" in a blank provided with each one. For those that are considered applicable, either the requirement or verification procedure is then fully defined. Additionally, unique requirements can be added as a direct product of the tailoring process.

FLIGHT LOADING CONDITIONS

The flight conditions (subsection of 3.4) consists of thirteen categories, from the standard symmetrical manauvare, to missile evasion, to the all inclusive "Other" category which is the one that both frees the designer from rigid requirements and simultaneously burdens him with the need to better define anticipated usage. The maneuver load catagory suggests a minimum of five sub-categories for consideration. There is, of course, the usual symmetric maneuver envelope, figure 3. However, due to current usage, various maneuvers such as extreme yaw, jinking, or missile lock evasion are suggested for design consideration. Any maneuver which is possible for an anticipated aircraft and its usage, must be considered for design purposes.

Other changes can be found in the area of turbulence analysis. Historically, gust loading conditions have been analysed by a discrete approach. However, the current procedura is to employ an exceedance distribution calculation. In order to establish the exceedance distribution, various parameters are needed. Fortunately, the new specification does suggest values for these terms; figure 4 is an exampla from the specification. Also, historically, maneuver and gust loadings were considered independent end non-concurrent of each other except for aircraft engaged in low altitude missions. However, MIL-A-87221 actually suggests the designer rationally consider various conditions where gust and maneuver loads are combined because they concurrently affect the aircraft.

A vary different type of load condition occurs during in-flight refueling. While some services use the probe and drogue system, a few others use the flying boom approach; a few use both types of in-flight refueling systems. This specification provides guidance in both these areas to establish appropriate design conditions.

Since the very beginning of aircraft pressurization, specifications have addressed its loading effects. However, this new specification addresses pressurization in a more inclusive manner then in the past. Usually, pressurization concerns have been focused on cockpits or crew compartments. In contrast, the new specification addresses all portions of the aircraft structure subject to a pressure differential. The requirements to consider pressurization even apply to such areas as fuel tanks, avionics bays, or photographic compartments. The broad application of this section of the specification requires constant and capable vigilance by the designer to include all pertinent structure.

Since this specification does not presume to directly address all possible loading phenomena, a special category is reserved for any unique situations. This category is called "Other" and is available so the designer can completely define all anticipated aircraft flight loading conditions. The important aspect of this category is that the designer is free to include any flight loading condition derived from operational requirements that can be appropriately defined for analysis.

GROUND LOADING CONDITIONS

While aircraft ground operations are not as glamorous as flight performanca, they can be the source of significant loading conditions. Unlike flight conditions, there have been vary few changes to ground operating conditions in recent years. In some cases tha loading levels have been decreased due to improved civil engineering capabilities; improved runways, taxiways, ramps, etc. Ground loading conditions include all ground operations (taxi, landing, braking, etc.) and maintenance operations (towing, jacking, hoisting, etc.).

Ground Operations

Since the earliest days of aircraft, ground operations have changed very little. Most of these changes have been in the area of load magnitude, not in the type or source of load. Before takeoff, an aircraft normally needs to taxi, turn, pivot, and brake. Various combinations of these operations must be considered in order to fully analyze realistic gorund operations. The resultant loads are highly dependent on the operating conditions, which are in turn dependent on tha aircraft type and anticipated mission.

Takeoff and Landing.

Usually takeoffs and landings are performed on hard, smooth surfaces which are of more than adequate length. However, in some situations the surface is not of adequate length, hardness, or smoothness. Therefore, takeoff specifications must either anticipate all possible situations or allow the designer to establish specific takeoff and landing requirements for each system. For example, consideration is given to rough semi-prepared and unprepared surfaces. Even rocket and catapult assisted launch is included in the specification. However, the designer is free to consider devices such as ski-jumps, if they are appropriate to the aircraft and missions involved. Since takeoffs are addressed; so too are landings. Various surfaces, arrestment devices and deceleration procedures are included for consideration as possible load producing conditions. The designer and eventual user must work together to correctly establish landing requirements, since they can vary greatly depending on the final usage of the aircraft.

Towing

Since the beginning of aviation, it has been necessary to tow aircraft. While the designer is free to define his own towing conditions and associated loads, he must also verify the legitimacy of these conditions. In this category the new specification comes close to the previous Air Force criteria specifications by providing the values given in figures 5 and 6. One should remember that these towing conditions are very much a result of years of empirical experience. Justifying and verifying new towing load conditions could be a very difficult task.

Crashes

Unfortunately not all flights are successful; some end in crashes. Different types of aircraft require various types of design considerations for crash loads, depending on their inherent dangers due to mission and general configuration. For example, fighters pose crash problems with respect to seats, fuel tanks, or cockpit equipment, but definitely not litters or bunks. However, the design of a transport would most assuredly involve crash load considerations for cargo, litters, bunks, or even temporary fuel tanks in the cargo compartment. The new specification suggests various combinations of on-board equipment. These suggested values, figure 7, are very similar to the historic ones which in the past were firm requirements. Today a designer can use factors other than the suggested ones, as long as the alternate load factors can be substantiated.

Maintenance

Even daily maintenance actions can impose various loading conditions on aircraft. Many maintenance operations require towing, jacking, or hoisting which subject the aircraft to abnormal and unusual loading combinations that must be considered during aircraft design. General data is supplied for these conditions, figure 8. However, following the tailoring philosophy in MIL-A-87221 (USAF), the designer is free to define any level of maintenance induced loadings which can be substantiated.

CONCLUSIONS

The new specification, MIL-A-87221, will allow design requirements to be more closely tailored to the anticipated use of the aircraft. In this way the final product will be more efficient, with less wasted, unneeded, and unused capabilities. This will lead, in turn, to reduce costs of ownership for Air Force weapon systems. This specification has been applied to the definition of requirements for the Advanced Tactical Fighter. This process is now taking place.

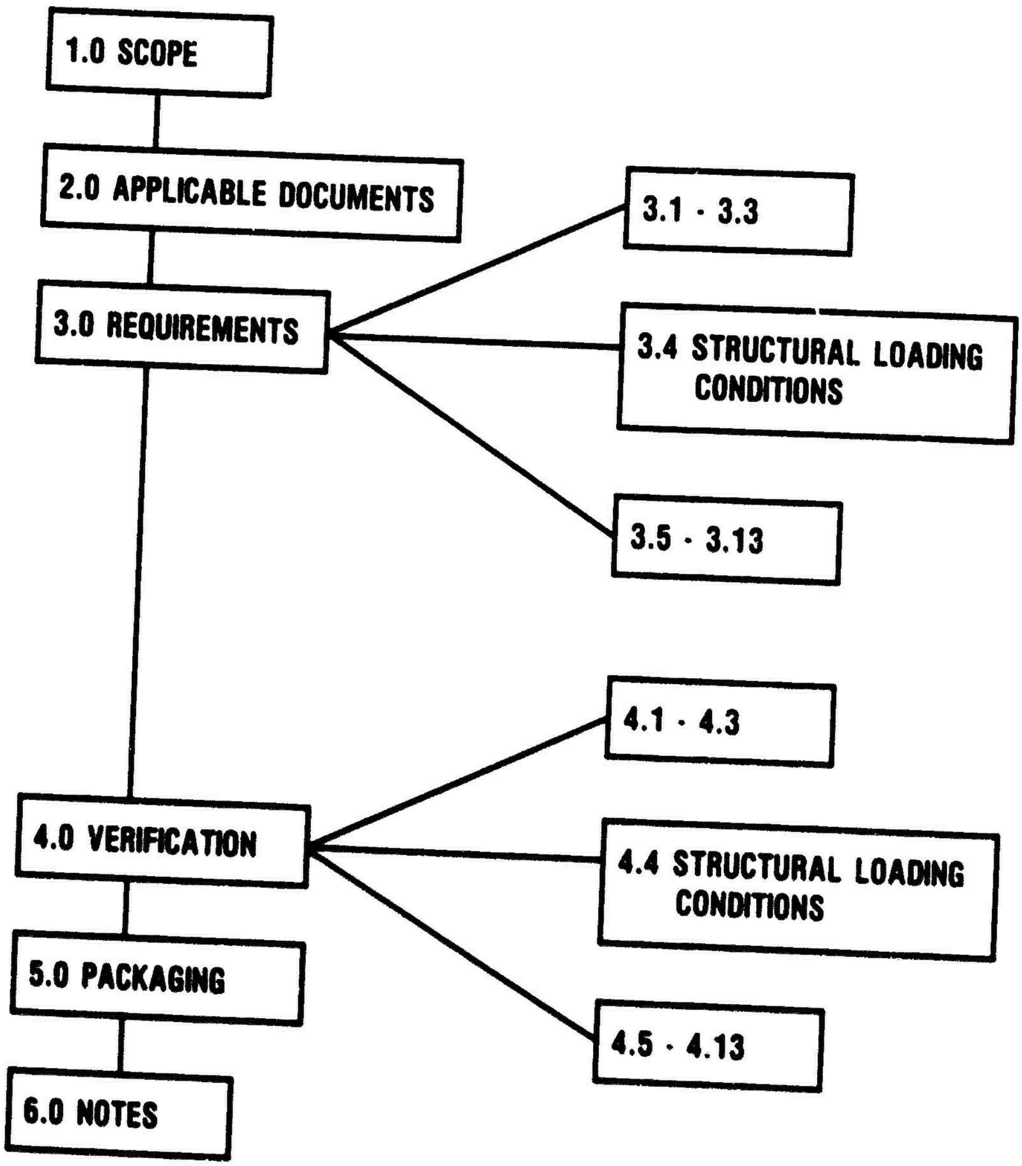


FIG. 1 ORGANIZATION OF MIL-A-87221 (USAF)

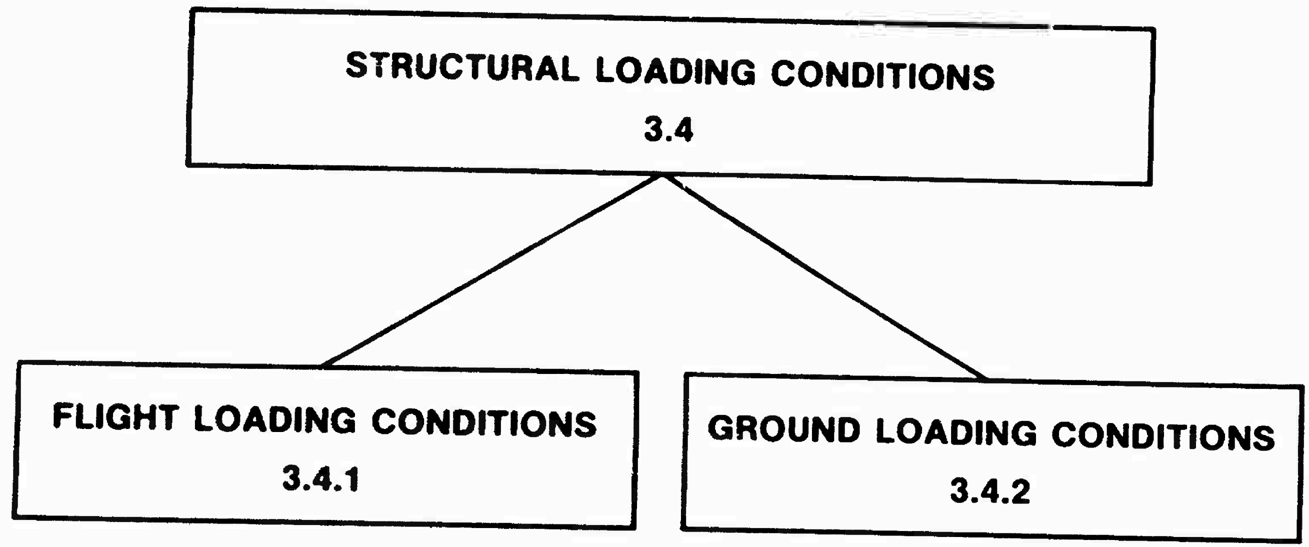


FIG. 2 ORGANIZATION OF "STRUCTURAL LOADING CONDITIONS"

FLIGHT LOADING CONDITIONS

3.4.1

3.4.1.1 SYMMETRIC MANEUVERS
3.4.1.2 ASYMMETRIC MANEUVERS
3.4.1.3 DIRECTIONAL MANEUVERS
3.4.1.4 EVASIVE MANEUVERS
3.4.1.5 OTHER MANEUVERS
3.4.1.6 TURBULENCE
3.4.1.7 AERIAL REFUELING
3.4.1.8 AERIAL DELIVERY
3.4.1.9 SPEEDS AND LIFT CONTROL
3.4.1.10 BRAKING WHEELS IN AIR
3.4.1.11 EXTENSION AND RETRACTION OF LANDING GEAR
3.4.1.12 PRESSURIZATION
3.4.1.13 OTHER FLIGHT LOADING CONDITIONS

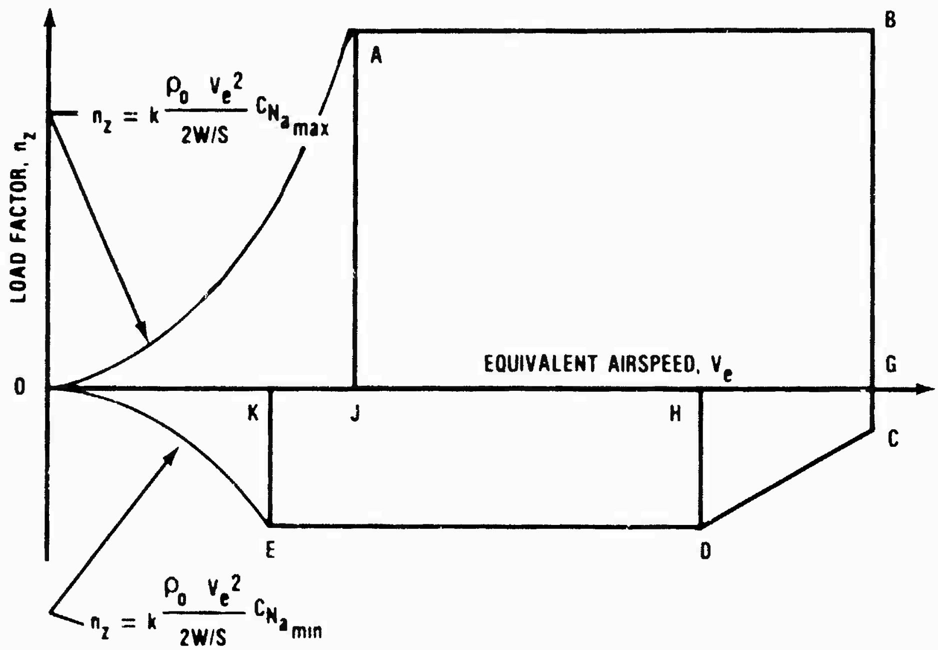
FIG. 2A FLIGHT LOADING CONDITIONS

GROUND LOADING CONDITIONS

3.4.2

3.4.2.1	TAXI
3.4.2.2	TURNS
3.4.2.3	PIVOTS
3.4.2.4	BRAKING
3.4.2.5	TAKEOFF
3.4.2.6	LANDINGS
3.4.2.7	SKI EQUIPPED AIR VEHICLES
3.4.2.8	MAINTENANCE
3.4.2.9	GROUND WINDS
3.4.2.10	CRASHES
3.4.2.11	OTHER GROUND LOADING CONDITIONS

FIG. 2B GROUND LOADING CONDITIONS



NOTES:

1. JA = GB = VALUE SPECIFIED IN PARAGRAPH 3.2.9
2. GC = VALUE SPECIFIED IN PARAGRAPH 3.2.9
3. HD = KE = VALUE SPECIFIED IN PARAGRAPH 3.2.9
4. OH = V_H AS SPECIFIED IN PARAGRAPH 3.2.7
5. OG = V_D OR V_L AS SPECIFIED IN PARAGRAPH 3.2.7

FIG. 3 V - n DIAGRAM FOR SYMMETRICAL FLIGHT AS PRESENTED IN MIL-A-87221 (USAF)

ALTITUDE (FT)	MISSION SEGMENT	DIRECTION 1/	P_1	b_1 (FT/SEC)	P_2	b_2 (FT/SEC)	L (FT) 2/
0 - 1,000	LOW LEVEL CONTOUR	VERTICAL	1.00	2.70	10^{-5}	10.65	500
0 - 1,000	LOW LEVEL CONTOUR	LATERAL	1.00	3.10	10^{-5}	14.06	500
0 - 1,000	CLIMB, CRUISE, DESCENT	VERT & LAT	1.00	2.51	005	5.04	500
1,000 - 2,500	CLIMB, CRUISE, DESCENT	VERT & LAT	.42	3.02	.0033	5.94	1750
2,500 - 5,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.30	3.42	.0020	8.17	2500
5,000 - 10,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.15	3.59	.00095	9.22	2500
10,000 - 20,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.062	3.27	.00028	10.52	2500
20,000 - 30,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.025	3.15	.00011	11.88	2500
30,000 - 40,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.011	2.93	.000095	9.84	2500
40,000 - 50,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.0046	3.28	.000115	8.81	2500
50,000 - 60,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.0020	3.82	.000078	7.04	2500
60,000 - 70,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.00088	2.93	.000057	4.33	2500
70,000 - 80,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.00038	2.80	.000044	1.80	2500
ABOVE 80,000	CLIMB, CRUISE, DESCENT	VERT & LAT	.00025	2.50	0	0	2500

NOTES: 1/ PARMETER VALUES LABELED VERT & LAT ARE TO BE USED EQUALLY IN BOTH THE VERTICAL AND LATERAL DIRECTIONS.

2/ FOR ALTITUDES BELOW 2,500 FT, THE SCALE OF TURBULENCE, L, CAN BE ASSUMED TO VARY DIRECTLY WITH ALTITUDE.

FIG. 4 SAMPLE OF TURBULENCE FIELD PARAMETERS

CONDITION	TOWING LOAD		ROTATION OF AUXILIARY WHEEL RELATIVE TO NORMAL POSITION	TOW POINT
	DIRECTION FROM FORWARD, DEGREES	MAGNITUDE		
1	0	0.75 T		AT OR NEAR EACH MAIN GEAR
2	±30			
3	180			
4	±150			
5	0	T	0	AT AUXILIARY GEAR OR NEAR PLANE OF SYMMETRY
6	180			
7	0	T	180	
8	180			
9	MAXIMUM ANGLE	0.5 T	MAXIMUM ANGLE	
10	MAXIMUM ANGLE PLUS 180			
11	MAXIMUM ANGLE	0.5 T	MAXIMUM ANGLE PLUS 180	
12	MAXIMUM ANGLE PLUS 180			

FIG. 5 SUGGESTED TOWING CONDITION

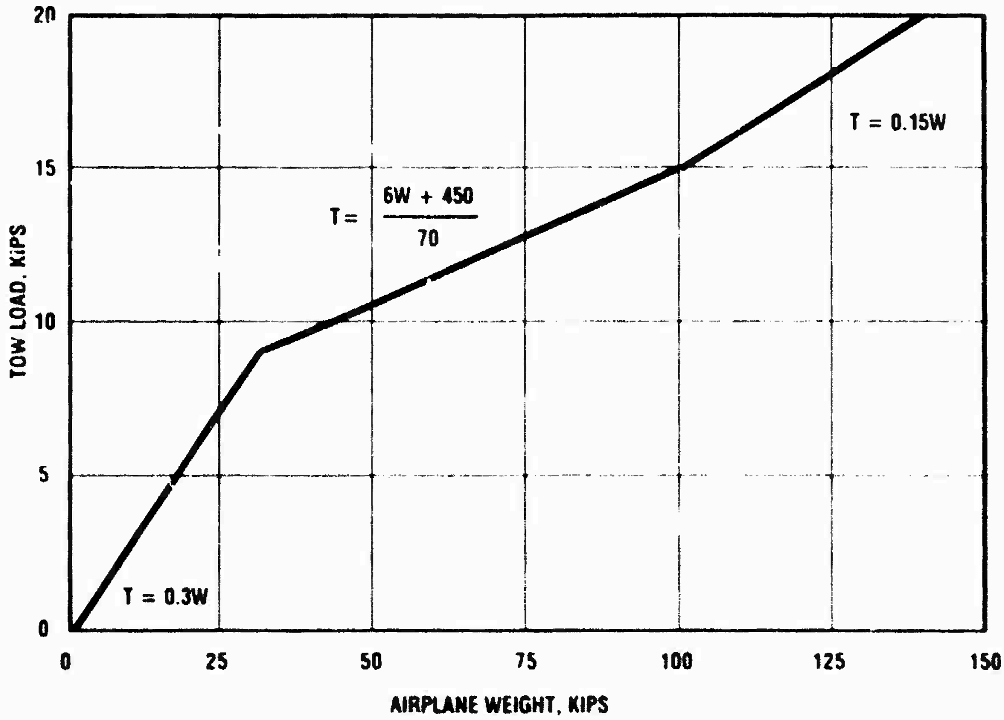


FIG. 6 SUGGESTED RELATIONSHIP BETWEEN AIRCRAFT WEIGHT AND TOW LOAD

BASIC MISSION SYMBOLS	LOAD FACTORS				APPLICABLE ITEMS
	LONGITUDINAL		VERTICAL	LATERAL (LEFT AND RIGHT)	
	FORWARD	AFT			
ALL AIRPLANES EXCEPT CARGO (C)	40	20	10 UP 20 DOWN	14	APPLICABLE TO ALL ITEMS
	20	10	10 UP 20 DOWN	10	APPLICABLE TO ALL ITEMS EXCEPT STOWABLE TROOP SEATS
CARGO (C)	10	5	5 UP 10 DOWN	10	APPLICABLE TO STOWABLE TROOP SEATS

FIG. 7 SAMPLE SEAT CRASH LOAD FACTORS SHOWN IN MIL-A-87221 (USAF)

COMPONENT	LANDING GEAR 3-POINT ATTITUDE	OTHER JACK POINTS LEVEL ATTITUDE
VERTICAL	1.35 F	2.0 F
HORIZONTAL	0.4 F	0.5 F
F IS THE STATIC VERTICAL REACTION AT THE JACK POINT.		

FIG. 8 SAMPLE JACKING LOADS GIVEN IN MIL-A-87221 (USAF)